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TWO COPIES OF TITLE 21 ARE SHOWN ON THIS WEB PAGE. THE FIRST IS THE MOST RECENT VERSION FILED 5-1-98; OPERATIVE 5-31-98 (REGISTER 98, No. 18). THE SECOND COPY IS THE ORIGINAL TITLE 21 WITH THE 1993 AMENDMENTS

TITLE 21

Article 1. Summary of Key Compatibility Specifications for Automatic Vehicle Identification Equipment

~ 1700. Summary.

The Compatibility Specifications for automatic vehicle identification (AVI) equipment have been developed around two principal components: a reader and a transponder. The minimum role of the reader is to:

- 1) trigger or activate a transponder.
- 2) poll the transponder for specific information, and
- 3) provide an acknowledge message to the transponder after a valid response to the polling message has been received.

A half-duplex communications system is envisioned where the transponder takes its cues from the reader.

The specification is meant to define a standard two way communications protocol and to further define an initial set of data records.

A summary of the key compatibility specifications found in this Chapter are set forth below:

Reader Specifications:

Reader Trigger Signal	33 microseconds of unmodulated RF
Reader Send Mode (Downlink)	
Carrier Frequency:	915 \pm 13 MHz (subject to FCC assignment)
Carrier Modulation:	Unipolar ASK (Manchester Encoded)
Data Bit Rate:	300 kbps
No. Data Bits:	Application Specific
Field Strength	
at Transponder Antenna:	500 mV/m (minimum)

Transponder Specifications:

Technology Type	Modulated Backscatter
Transponder Antenna Polarization:	Horizontal
Field-of View	Operation within 90° conical angle
Location:	Front of Vehicle
Transponder Send Mode (Uplink)	
Carrier Frequency:	Same as Reader Send Mode
Carrier Modulation:	Subcarrier AM
Subcarrier Modulation:	FSK
Subcarrier Frequencies:	600 kHz \pm 10% and 1200 kHz \pm 10%
Data Bit Rate:	300 kbps

No. Data Bits:	Application Specific
Receiver Field-Strength Threshold:	500 mV/m \pm 50 mV/m (minimum)

Note: All mV/m specifications are RMS voltage.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New chapter 16, article 1-4 and sections 1700-1705.8, not consecutive filed 6-26-92; operative 7-27-92 (Register 92, No. 26).
2. Amendment filed 5-1-98; operative 5-31-98 (Register 98, No. 18).

~ 1701. Definition of Technical Terms.

The Following are definitions of technical terms used throughout this Chapter:

- (a) AM - Amplitude Modulation
- (b) ASK - Amplitude shift keying
- (c) BCC - Block check character
- (d) CRC - Cyclic redundancy check
- (e) CW - Continuous wave
- (f) EIRP - effective isotropically radiated power = gain x net power
- (g) EM - Electromagnetic
- (h) FCC - Federal Communications Commission
- (i) FSK - Frequency-shift keying
- (j) ID - Device identification
- (k) kbps - kilobits per second
- (l) kHz - kilohertz (10^3 hertz)
- (m) kph - kilometer per hour
- (n) MHz - megahertz
- (o) m/Vm - milliVolts/meter
- (p) Reader - A fixed-position reader, associated transmit and receive (Tx/Rx) antenna(s), and modulation and demodulation hardware and software.
- (q) RF - Radio frequency
- (r) Transponders - Electronic devices that contain information which can be communicated to the reader. The transponders may have the capability to read and write information.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).

2. Amendment of subsections (c)-(e), new subsection (o), subsection relettering, and amendment of newly designated subsection (r) filed 5-1-98; operative 5-31-98 (Register 98, No. 18).

Article 2.0. Introduction

~ 1702.1. Objectives

This chapter defines the compatibility requirements for automatic vehicle identification (AVI) equipment. Supplemental Agency (e.g., Toll Authority) specifications will detail the technical, environmental, and operational specifics for each site implementation. The immediate mandate for this compatibility specification is for electronic toll collection.

AVI equipment will essentially consist of two functional elements: vehicle-mounted transponders and fixed-position reader units.

The specification is meant to define a standard communications protocol and to further define an initial set of data records. The initial data records are designed for voluntary implementations of electronic toll collection.

It is further envisioned that the more complex data records will be developed to handle anonymous transactions, secure funds transfers, information transfers, and other transactions between the reader and the transponder that will be defined as needed. The transponders may have the capability to read and write information. Caltrans shall function as the standards monitoring authority to authorize the use of new record types and to assign record type numbers to newly authorized records. Caltrans shall pass this responsibility to an appropriate standards setting organization when one is established and recognized with Caltrans retaining representation in the standards setting organization.

Nothing in these regulations shall preclude the addition of functions and technologies to the transponder and/or reader systems.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).
2. Amendment adding last sentence filed 2-16-93: operative 3-18-93 (Register 93, No. 8).
3. Amendment of first and fourth paragraphs filed 5-1-98; operative 5-31-98 (Register 98, No. 18).

~1702.2. Organization.

This Chapter consist of four articles. An overview and summary of the key specifications is given in Article 1. Article 2 presents the objectives and definitions for data codes. Articles 3 and 4 provide specifications unique to the reader and transponder respectively.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).

~1703. Definitions for Data Codes.

- (a) Agency Code: This 16-bit code field identifies the agency that has authority to conduct the transaction.
- (b) Byte Order: Numeric fields shall be transmitted most significant bit first. If a numeric field is represented as multiple bytes, the most significant bit of the most significant byte is transmitted first. This document represents the most significant and first transmitted to the left on a line and to the top of a multi line tabulation.
- (c) Error Detection Code: The error detection code utilized in the defined records is the CRC-CCITT, with a generator polynomial of $X^{16} + X^{12} + X^5 + 1$. This results in a 16-bit BCC transmitted with each data message. The data field protected by the CRC excludes any preceding header in every case.
- (d) Filler Bits: Filler bits are used to adjust the data message length to a desired length and shall be set to zero.
- (e) Header Code: The header is the first field in each data message for either reader or transponder transmissions and consists of an 8-bit and a 4-bit word for a total of 12 bits. The header provides a signal that may be used by a receiver to self-synchronize (selsyn) with the data being transmitted, thus the notation selsyn. The selsyn signal has binary and hexadecimal values: 10101010 and AA, respectively.
The Header code also provides for a unique, 4-bit flag that is recognized by a receiver decoder as the end of the header with the data message to follow. The flag signal has binary and hexadecimal values: 1100 and C respectively.
- (f) Reader ID Number: This 32-bit field is used to uniquely identify the reader conducting the transaction.
- (g) Transaction Record Type Code: This 16-bit code uniquely identifies a specific type of valid transaction between a reader and a transponder. This code uniquely defines the transponder message fields and functions permissible with the transaction type specified by the polling message as described in Section 1704.5(e)(1). Hexadecimal numbers 1 through 7FFF are

set aside for transponder message structures and 8000 through FFFF are dedicated for reader-to-transponder message structures.

- (h) Transaction Status Code: Used to provide status information to the transponder.
- (i) Transponder ID Number: This 32-bit code uniquely identifies which transponder is responding to a polling request or is being acknowledged.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).
2. Amendment of subsections (a), (c), (e) and (g) filed 5-1-98; operative 5-31-98 (Register 98, No. 18).

Article 3. Reader Specifications

~ 1704.1. General.

The reader will transmit a RF trigger pulse to activate (turn-on) the transponders. After a time delay, the reader then will transmit an encoded signal, referred to as the polling message which, upon detection and decoding by the transponder, will provide initial information to the transponder including the type of transaction the reader wishes to conduct.

The reader will then transmit an unmodulated CW RF signal for the transponder to modulate with a data message while backscattering to the reader. The reader may repeat the polling-to-backscattering sequence until it obtains an error free data message from the transponder. The reader will then transmit an encoded acknowledge message to the transponder providing status information and requesting that the transponder not respond to the same polling message again for a fixed time period.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).
2. Amendment filed 5-1-98; operative 5-31-98 (Register 98, No. 18).

~1704.2. RF Carrier Frequency.

The RF carrier frequency shall be taken from the 915 MHz \pm 13 MHz range. Specific frequency and bandwidth depend upon pending FCC assignment.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).

~1704.3. Reader Antenna Specifications.

(a) Reader Antenna Polarizations.

The reader transmit and receive antennas shall have predominant EM field components that are co-polarized to the horizontal polarization specified for the transponder transmit and receive antennas in section 1705.3(a).

Horizontal linear, circular or elliptical polarizations are allowed.

(b) Reader Antenna Location.

The reader antenna location is site specific.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).
2. Amendment of subsection (a) filed 5-1-98; operative 5-31-98 (Register 98, No. 18).

~1704.4. Reader-To-Transponder Trigger Pulse.

(a) Trigger Pulse Definition.

The reader shall provide a wakeup trigger for the transponder. The trigger shall consist of a 33 microsecond long, RF pulse at the assigned carrier frequency that is modulated with a continuous string of ones. The trigger pulse shall be followed immediately by a delay (i.e., no RF transmission) of 100 microseconds duration. The wakeup pulse is intended to signal a dormant transponder to fully activate itself.

(b) Trigger Pulse Field Strength.

The required horizontal component of field strength produced by the trigger pulse at the maximum downlink range (site dependent) of the reader shall be greater than 500 mV/m.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).

1704.5. Reader Communications Protocol.

- (a) AM Modulation Scheme.
The downlink (reader-to-transponder) modulation scheme shall be unipolar ASK of the RF carrier using Manchester encoding. A data bit '1' is transmitted by sending an RF pulse during the first half of the bit period and no signal during the second half, while for a '0' data bit the reverse order is used; i.e., no signal during the first half of the bit period and an RF pulse transmission during the second half.
- (b) Data Bit Rates.
The data bit rate for reader-to-transponder messages shall be 300 kbps.
- (c) Field Strength.
The field strength of a reader data message at the transponder shall be greater than 500 mV/m.
- (d) Standard Reader Data Message Format.
The standard portion of a reader data message shall consist of a header and transaction record type code. The subsequent length, data content, and error detection scheme shall then be established by the definition for that transaction record type.
- (e) Reader Data Message Formats for AVI.
There may be several reader-to-transponder data message formats. The format is determined by the transaction record type code sent by the reader. The following is the reader-to-transponder message format presently specified for AVI electronic toll collection applications:
 - (1) Reader Transaction Record Type 1 (Polling Message).
The polling message (which follows the 100 microsecond delay after the trigger signal) tells the transponder the type of transaction the reader wishes to conduct. For AVI electronic toll collection applications, reader transaction record type 1 (polling message) also would identify the agency or toll authority. For AVI applications, the reader-to-transponder type 1 polling message shall be structured using the following ordered data bit fields:

<i>Field Definition</i>	<i>No. Bits</i>	<i>Hexadecimal Value</i>
Header Code		
Selsyn	8	AA
Flag	4	C
Transaction Record Type Code	16	8000
Agency Code	16	
Error Detection Code	<u>16</u>	
Total:	60	

(2) Reader Transaction Record Type 2 (Acknowledge Message).

A reader-to-transponder acknowledge data message shall be provided to inform specific transponders that they have been successfully processed and to stop responding to further identical reader polling requests. The acknowledge message is used to terminate the transaction, and is only sent if the transaction is successfully completed. Reader transaction record type 2 (acknowledge message) shall consist of the following ordered data bit fields:

<i>Field Definition</i>	<i>No. Bits</i>	<i>Hexadecimal Value</i>
Header		
Selsyn	8	AA
Flag	4	C
Transaction Record Type Code	16	C000
Transponder ID Number	32	
Reader ID Number	32	
Transaction Status Code	16	
Error Detection Code	<u>16</u>	
Total:	124	

(f) Reader End-of-Message Frame.

The end-of-message signal for reader-to-transponder data messages shall consist of a minimum of 10 microseconds of no RF carrier signal.

Transponder decoders shall have the ability to detect this condition as an invalid Manchester Code.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).
2. Amendment of subsections (d)-(f) filed 5-1-98; operative 5-31-98 (Register 98, No. 18).

~1704.6. Reader Field Strength for Modulated Backscattering.

The electric field strength produced by a reader is a function of the EIRP. The EIRP required to detect a modulated backscattered RF signal from a transponder with a reasonably high signal-to-noise ratio is determined by the maximum range to the transponder and the detection sensitivity of the reader receiver plus any gain margin. If the overall gain characteristics of the transponder were held constant, the required EIRP then becomes site dependent.

The electric field strength to accomplish modulated backscattering is expected to be lower than that required for triggering a transponder or for sending a reader

data message. Sensitive reader receivers likely will be necessary, however, such as that obtained with homodyne or heterodyne technology.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).
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Article 4. Transponder Specifications

~1705.1. General Description.

Transponders will be encoded with unique identification data together with other coded data as described in this section. On passing through any AVI reader zone, the transponder will provide the coded data to the reader only on receipt of a valid reader polling command. Transponders must be capable of being turned on and off as specified herein. Transponders must be capable of two-way data communications. Transponders may be portable. The transponders may have capability to read and write information

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).
2. Amendment filed 5-1-98; operative 5-31-98 (Register 98, No. 18).

~1705.2. Transponder RF Carrier Frequency.

The transponder RF carrier frequency in a backscatter system is identical to that used by the reader, the frequency will be in the range of 915 MHz \pm 13 MHz.

The transponder shall be capable of operating over the full \pm 13 MHz band to allow site flexibility in reader implementation.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).

~1705.3. Transponder Transmit and Receive Antennas.

(a) Antenna Polarizations.

The transponder transmit and receive antennas shall have EM field components that are predominantly horizontally polarized transverse to normal traffic flow. Horizontal, linear, circular or elliptical polarizations are allowed.

(b) Antenna Field of Views.

The transponder transmit and receive antennas shall have a field of view which is a 90 deg. cone in front of the vehicle. The projection of the horizontal component of the cone's axis shall be parallel to the lane and the vertical component of the cone's axis shall be 35 deg. horizontal.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).
2. Amendment of subsection (a) filed 5-1-98; operative 5-31-98 (Register 98, No. 18).

~1705.4. Transponder Activation.

(a) Activation Timing

Within 1 millisecond of entry into the reader's modulated RF field, a transponder shall be fully activated and ready to decode the polling message from the reader within 100 microseconds of receipt of a 33 microsecond long modulated RF trigger pulse from the reader.

(b) Activation Timing for Battery Power Management.

As an alternative to 1705.4(a), delay of 20 additional milliseconds is permissible for a transponder using multiple-state activation to conserve battery life. Within 21 milliseconds of entry into the reader's modulated RF field, such a transponder shall be fully activated and ready to decode the polling message from the reader within 100 microseconds of receipt of a 33 microsecond long modulated trigger pulse from the reader.

(c) Activation Field Strength.

The transponder receiver shall be capable of recognizing and acting on a trigger signal and polling message when the free-space field strength at the transponder location exceeds 550 mV/m and will not respond to field strengths below 450 mV/m (Electric field strengths are to be measured in free-space and in the absence of any vehicle). After completion of the Polling message, the transponder shall begin modulating and backscattering RF with continuous zero bits. 100 microseconds after completion of the polling message, the transponder shall begin transmitting its message. If a newly

activated transponder does not immediately receive a polling message, it shall remain activated and ready to receive a subsequent reader message for at least 20 milliseconds.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).
2. Repealer and new section filed 5-1-98; operative 5-31-98 (Register 98, No. 18)

~1705.5. Transponder Communications Protocol.

- (a) Subcarrier Modulation Scheme.
The transponder-to-reader (uplink) modulation scheme shall be amplitude modulation of an RF carrier backscatter created by varying the reflecting cross-section of the antenna as seen by the incident carrier signal. The antenna cross-section shall be varied between upper and lower limits with a 50 percent duty cycle and rise and fall times of less than 75 nanoseconds. The transponder baseband message signal shall modulate the subcarrier using FSK modulation with a center frequency of 900 kHz and frequency deviation of ± 300 kHz. The lower and upper subcarrier frequencies correspond to data bits '0' and '1' respectively. The message information is conveyed by the subcarrier modulation frequencies of the transponder backscattered signal and not by amplitude or phase.
- (b) Data Bit Rates.
The data bit rate for transponder-to-reader data messages shall be 300 kbps.
- (c) Field Strength.
The field strength at which a transponder data message is transmitted using backscatter technology is dependent upon the incident field strength from the reader, the transponder receive and transmit antenna gains, and any RF gain internal to the transponder. The transponder and antenna gain taken together shall effect a change in the backscattering cross-section of between 45 and 100 square centimeters.
- (d) Standard Transponder Data Message Format.
The standard portion of a transponder data message shall consist of a header and transaction record type code. The subsequent length, data content and error detection scheme shall then be established by the definition for that transaction record type.
- (e) Transponder Data Message Formats for AVI Toll Collection.
There may be numerous transponder-to-reader data message formats. The format is determined by the transaction record type code sent by the

transponder. The following is the reader-to-transponder message format presently specified for AVI electronic toll collection applications:

(1) Transponder Transaction Type 1 (Data Message).

Transponder transaction type 1 (data message) allows for unencrypted transponder ID numbers to be transmitted. Type 1 (data messages) shall be structured using the following ordered data bit fields:

<i>Field Definition</i>	<i>No. Bits</i>	<i>Hexadecimal Value</i>
Header Code		
Selsyn	8	AA
Flag	4	C
Transaction Record Type Code	16	1
Transponder ID Number	32	
Error Detection Code	<u>16</u>	
Total:	76	

(f) Transponder End-of-Message Frame

The End-of-Message signal for transponder data messages shall consist of a minimum of 10 microseconds of no modulation.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).
2. Amendment of subsections (d) - (e) (1) filed 5-1-98; operative 5-31-98 (Register 98, No. 18).

~1705.6. Transponder Response to Reader Acknowledge Message.

The transponder shall discontinue responding to identical reader polling requests for a period of 10 seconds once a valid reader acknowledgement message has been received. The transponder shall, however, respond to polling messages that are not identical to the polling message that lead to the valid acknowledgement.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).
2. Amendment filed 5-1-98; operative 5-31-98 (Register 98, No. 18).

~1705.7. Multiple Transponder Responses to a Reader Polling Message.

Each transponder data message transmittal must be in response to a reader polling message.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).

~1705.8. Transponder Positioning.

Transponders shall be positioned at the front of the vehicle with a clear line of sight to the reader antenna without degrading the performance of the reader-transponder system below minimum specified standards. As a minimum, transponders shall operate up to a maximum of 76 cm (30") offset from the longitudinal center line of the vehicle.

The front of the vehicle shall be defined as that portion of the vehicle from the driver's eyes forward.

Note: Authority cited: Section 27565, Streets and Highways Code. Reference: Sections 27564 and 27565, Streets and Highways Code.

History

1. New section filed 6-26-92: operative 7-27-92 (Register 92, No. 26).
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